A Subsurface Study of the Packer Shell of Ohio

A Senior Thesis Presented in Partial Fulfillment of the Requirements for the Degree Bachelor of Science, Department of Geology & Mineralogy, The Ohio State University, June 1981.

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The purpose of this project was to determine the nature of the "Packer Shell", and its' reliability as a useful datum plane. The "Packer Shell", a drillers' name used in industry and a formation belonging to the Clinton Group and Silurian in age, is about fifty feet above the "Clinton Sandstone", an important oil- and gas-producing formation in Ohio. The "Packer Shell" is also considered to be a "cap rock" for the "Clinton Sandstone". As a part of the project an east-west cross-section showing the Packer Shell and other formations was constructed across Ohio, using subsurface data secured from gamma ray and bulk density logs.

Mr. William E. Shafer, Geologic Consultant of Shafer Exploration Inc., Columbus, Ohio, because of personal interest in the "Packer Shell", brought this project to my attention and taught me how to read and interpret geophysical logs. He also aided in final identification of the "Packer Shell" on the eleven logs used, which were copied from microfilm available at the Ohio Division of the Geological Survey. Information on each well-site is summarized in Table 1.

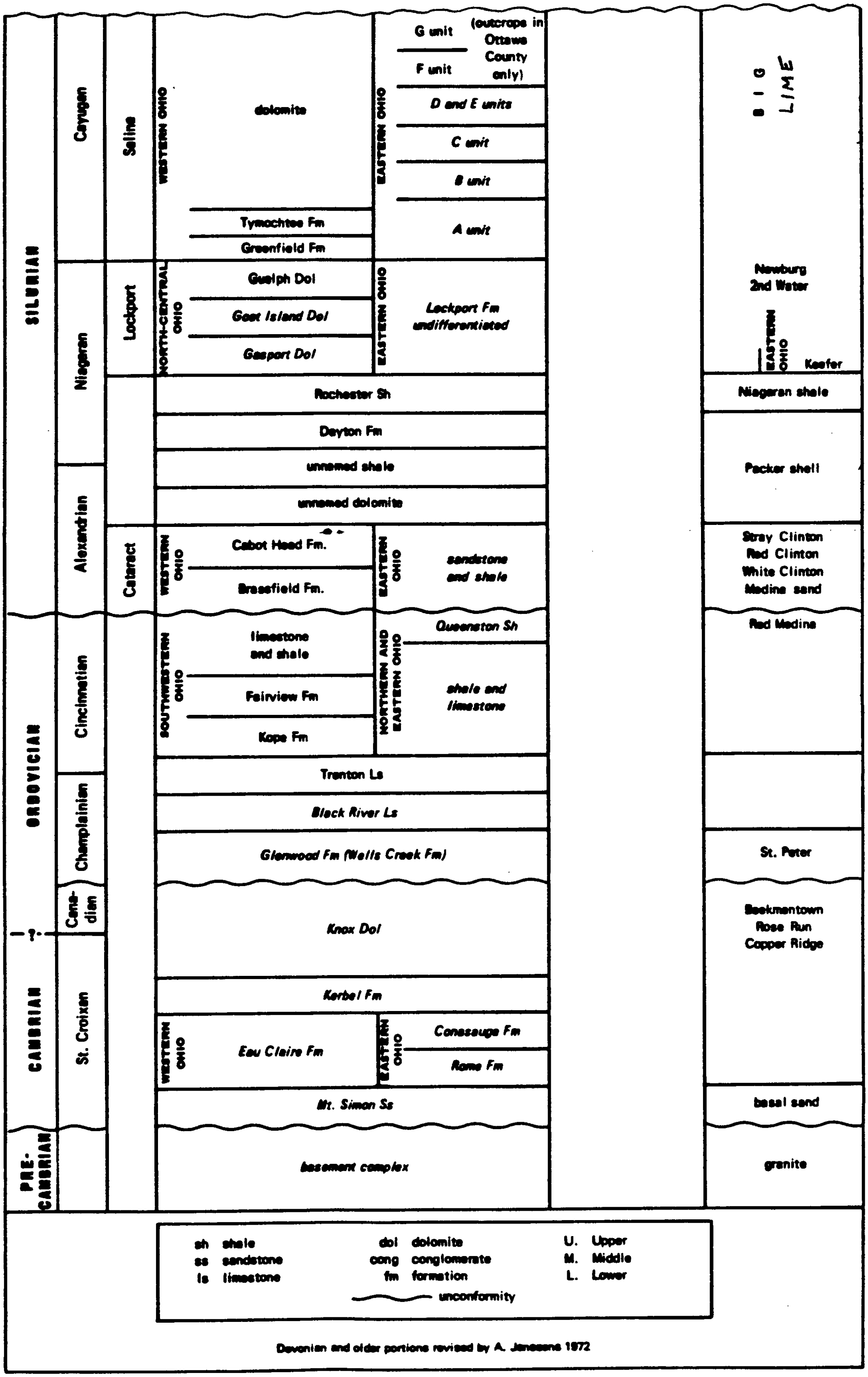
The "Packer Shell" is a drillers' name used in the field. One of my concerns was to determine the name for the unit that is used in stratigraphic classification. The unit has been considered the equivalent of the Brassfield Limestone or Dayton Formation, but after perusal of a study by Horvath (1964), in which he also constructed cross-sections of

I	II	III	IV	V	VI	VII	VIII	IX	X
	PERMIT NUMBER	COUNTY	TOWNSHIP	SECTION or LOT	DATE COMPLETED	GROUND ELEVATION	DEPTH OF BASE OF PACKER SHELL	PRESENT ELEVATION PACKER SHELL	INTER-HORIZONTAL DISTANCE
A	4	Fayette	Jasper	---	11/25/58	1040'	200'	+760?	32 mi. (A-B)
B	14	Pickaway	Jackson	---	6/12/65	765'	660'	+105'	27 mi. (B-C)
C	523	Fairfield	Berne	SW¼2	8/14/74	911'	2266'	-1355'	3.5 mi. (C-D)
D	314	Fairfield	Rushcreek	SE¼27	4/10/61	785'	2496'	-1711'	3 mi. (D-E)
E	3847	Perry	Jackson	SW¼5	12/15/76	820'	2722'	-1902'	6.5 mi. (E-F)
F	3640	Perry	Pike	NW¼4	9/25/75	930'	3248'	-2318'	10.5 mi. (F-G)
G	1389	Morgan	York	SW¼19	2/2/74	1080'	4008'	-2928'	8 mi. (G-H)
H	1311	Morgan	Bloom	SW¼13	2/11/73	965'	4596'	-3631'	4.5 mi. (H-I)
I	1387	Morgan	Bristol	SE¼9	1/21/74	690'	4550'	-3860'	8.5 mi. (I-J)
J	1490	Noble	Sharon	12	11/31/71	980'	5408'	-4428'	7.5 mi. (J-K)
K	1652	Noble	Enoch	SW¼6	4/18/75	903'	5814'	-4911	

Table 1: Data on selected wells represented on Plate I

Silurian strata through use of geophysical logs, I now think that the "Packer Shell" is not the equivalent of either the Brassfield or the Dayton, but perhaps is equivalent to what Horvath refers to as the Oldham Formation. However, because this project was done in consultation with Mr. Shafer, I chose to refer to the unit as the "Packer Shell". The Oil and Gas Fields of Ohio map includes a stratigraphic column correlating drillers' names of units with those formation names used in stratigraphic classification (Figure 1). In the cross-section (Plate I), the stratigraphic range generally shown is just above the base of the "Big Lime" to the top of the Queenston Shale or its western equivalent.

Originally, a structural cross-section was desired, however, because the scale of the gamma ray traced is one inch to forty feet, a structural cross-section would be physically impractical to construct (Table 1, Column IX). Because it was unknown whether the top of the "Packer Shell" was gradational or unconformable, the base of it was chosen as a datum plane. The "Packer Shell" was identified as being the most dolomitic limestone; that is, a reading on the graph to the extreme right (to be discussed on page 4). To check the accuracy of this, adjacent wells were carefully compared to see that the most logical identification of the "Packer Shell" was made. Furthermore, this identification was compared with that made by the well-site geologist as noted on the accompanying index cards. To determine the base of the "Packer Shell", two vertical lines were drawn on the gamma ray log. One was drawn through the points representing the highest radioactivity response (on the extreme right on the graph) and one was drawn through the points representing the



OIL & GAS FIELDS OF OHIO map; Ohio Department of Natural Resources

Figure 1: Correlation of drillers' or informal names (righthand column) with those of Stratigraphic Classification

lowest radioactivity response (to the extreme left on the graph). Where the midline between these two vertical lines intersected the segment of the curve that represents the bottom of the "Packer Shell", a horizontal line was drawn through this point and served as the base line of the "Packer Shell". This was done for each selected well in order to arrive at a consistent and accurate datum plane with differences in tools accounted for (Figure 2).

The desired density and detail of information in the westernmost portion of the state is lacking because of scarcity of wells and geophysical logs between wells A & B and B & C, due to the fact that most oil and gas occurs in the eastern half of Ohio. In addition, the existing wells in that area were drilled many years ago, and geophysical logging tools were not as advanced. The newest wells were selected in hopes that data obtained were based on the best technologically improved tools. In the extreme eastern part of the state along this cross-sectional line, the "Packer Shell" is very deep and most wells are not logged that deep. However, farther north, the "Packer Shell" is much shallower and the study could be extended to the east by offsetting the cross-section north and then east into Pennsylvania. However, doing so created the problem of correctly correlating the "Packer Shell" in the north with that in the east on the cross-section line, because it may undergo a facies change, being in a different position in the depositional basin. The most accurate way would be to do a detailed north-south study before continuing east.

In logging a well, different specialized tools are lowered into

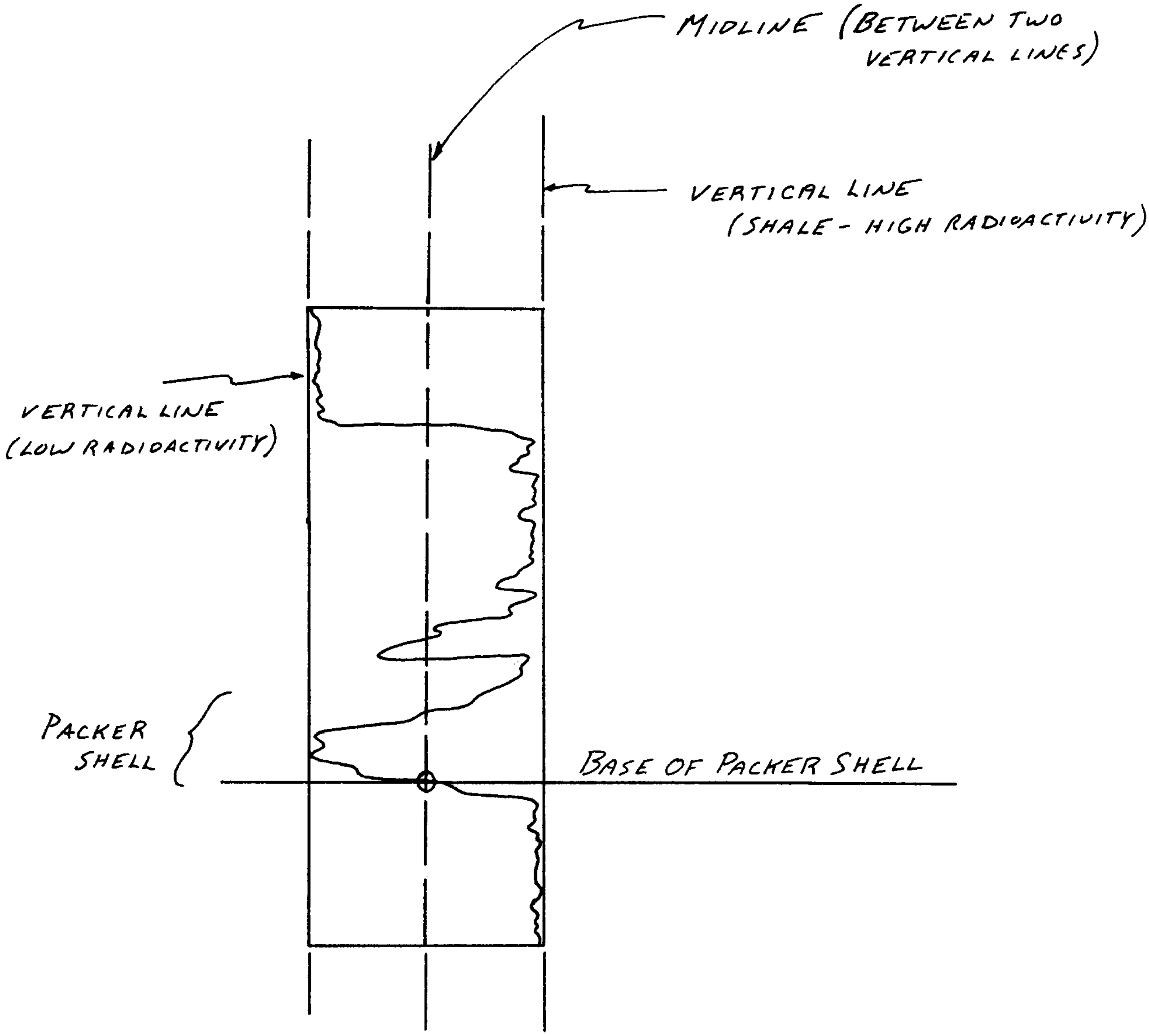


Figure 2: Method of determination of the base of the Packer Shell

the well hole after drilling; these tools measure different properties of the surrounding rock. The tools are equipped with sensors that pick up a characteristic of a particular property and deliver it through attached cables to the service truck. The response appears in graph form (that is called a log) on a screen in the truck at the well-site. It is also recorded on film, developed, and printed by a technician. Depth control is simultaneously maintained and recorded as the y-axis or ordinate. Thus, each different geophysical log has a unique graph. In order to obtain a greater understanding of the tools and the data, a description of each tool and an analysis of the graph is given.

The geophysical logs that I used in this study include the gamma ray, the neutron density, and the bulk density logs (Figure 3). The gamma ray is a relative measurement of the natural radioactivity in the strata of the earth. Anhydrite, salt, and coal are very low in radioactivity. Producing formations such as sandstone, limestone, and dolomite are relatively low in radioactivity. On the gamma ray log, high radioactivity is indicated by a reading to the right on the graph; a reading to the left is indicative of a low radioactive response and could reflect either a limestone or a sandstone.

The bulk density log records the density of the surrounding rock, and thus is an important aid in identifying lithology. Density also increases toward the right on the graph. A scale, commonly ranging from 2.1 to 2.8, is provided either at the top or the bottom of the graph. The scale readings and corresponding lithologic interpretations are in Table 2.

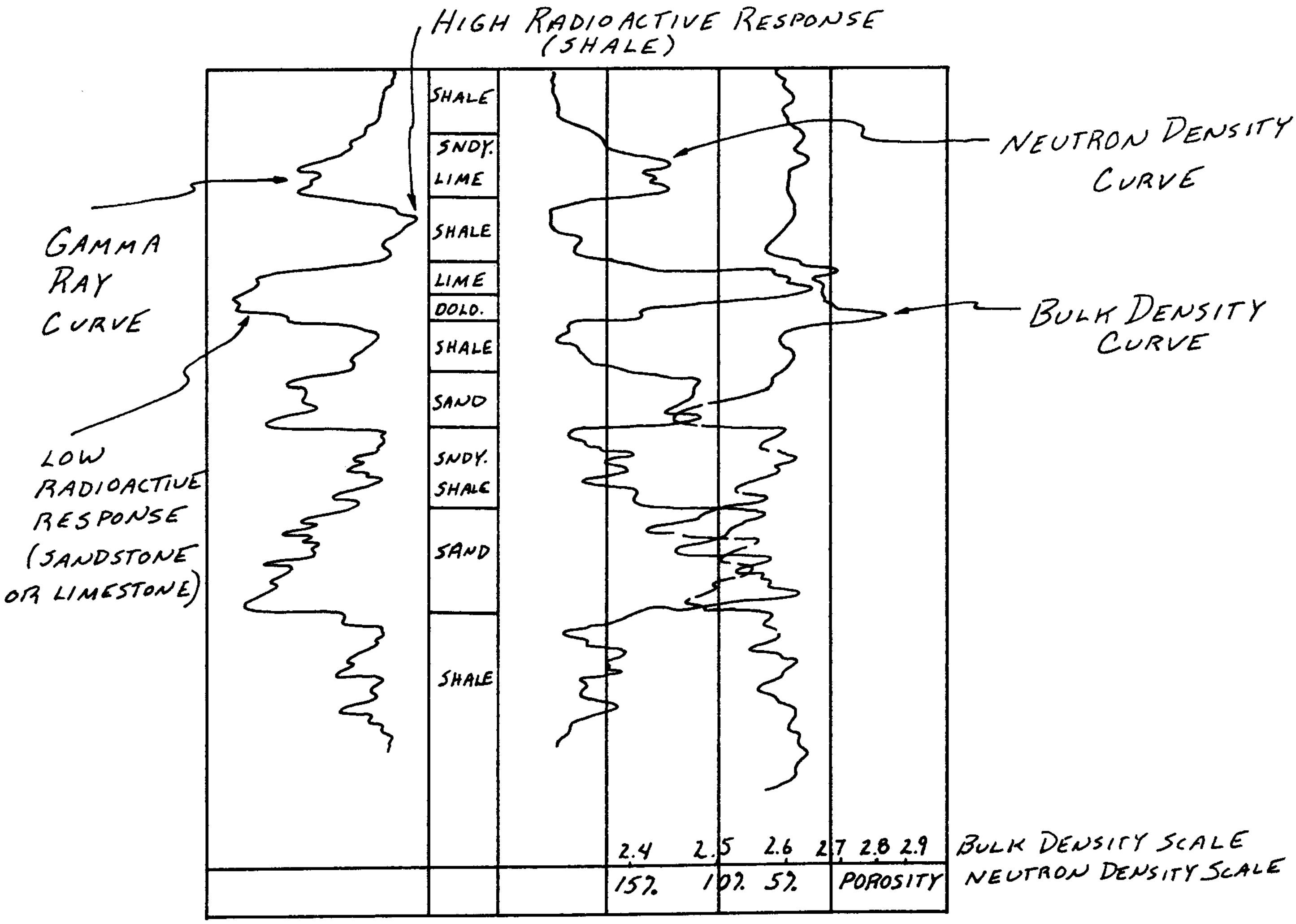


Figure 3: Sample log showing gamma ray, neutron density, and bulk density curves with corresponding lithologic interpretations.

Bulk Density	Rock Type
2.65 - 2.68	solid sandstone
2.71 - 2.76	limestone
2.85	dolomite
>2.85	anhydrite

Table 2. Bulk Density and corresponding rock type

Shale cannot be identified by use of the bulk density log, but it can be identified by the gamma ray log.

A neutron well log can be made after bombarding the strata with a strong source of fast-moving neutrons and is a record of the secondary gamma rays that have been excited by the neutron bombardment. The neutron curve is not adequate in identifying lithology. This curve is referred to as a "fluid content, or hydrogen curve", because hydrogen is the controlling factor in the logging. No matter whether the hydrogen occurs in gas, oil, water, or shale, the curve is characterized by a low reading on the graph to the left on the chart. Therefore, readings to the right are considered barren or impervious strata, whereas readings to the left are interpreted as possible porous zones.

Under the earlier impression that the "Packer Shell" was equivalent to either the Brassfield or Dayton Formation, I visited a locality described in detail by Pennell (1952) where the Brassfield and Dayton are exposed. This locality is the Marble Cliff Co. quarry on Euphemia-Castin Road, 1.3 miles northwest of Lewisburg, Ohio. Given permission by one of the sons of the quarry owner, who lived nearby, I was able to collect some samples of the Brassfield and Dayton. Polished rock and thin section study of these Silurian rocks provided insight into depositional environment and origin not obtainable from geophysical logs. Three thin sections and hand specimens will be discussed. One is from the Dayton Formation and two are from the Brassfield. An interpretation of the depositional environment of each also is presented.

Hand Specimen Description DF1

The Dayton from this locality is a fine-grained mottled bluish-gray and brownish-gray dolomitized limestone.

Thin Section Study

This finely crystalline dolomite contains some floating crinoids which indicate that the rock was a fossiliferous micrite that has been dolomitized. According to the classification scheme of Dunham, this rock is classified as a dolomitized wackestone. The darker bluish-gray color, recognizeable in hand specimen, is due to small, linear clusters of pyrite.

Depositional Environment (as indicated by this specimen)

Because it was originally lime mud, a low-energy environment is inferred; there was insufficient energy to carry the mud away. This low-energy environment could have been either shallow or deep water. A possibility is a lagoonal environment, in which a high concentration of magnesium could be built up over a long period of time and eventually precipitate out as dolomite, replacing micrite.

Hand Specimen Description BL1

The Brassfield Limestone, represented by this specimen, is a coarse-grained light pinkish-gray fossiliferous grainstone. According to Pennell (1952), hydrous iron-oxides formed from small grains of pyrite are the source of the pink color.* Styolitic seams transect the rock fabric.

Thin Section Study

According to Dunham, this specimen is a crinoidal calcarenite grainstone. It consists of skeletal grains, mainly crinoid plates and a few poorly preserved bryozoa and brachiopod fragments, a light brown interclast (approximately 6mm in length), and pelloids (ovoid micritic clasts). The dark material throughout the rock is probably organic material, appearing white under reflected light. It could possibly be phosphate. This material filled the pores of the skeletal fragments. For the most part, the skeletal grains lack organic structure and are recognized by shape. The original crinoid plates have been recrystallized and show syntaxial overgrowth. Syntaxial overgrowth occurs when calcite-rich waters fill in and cement over the crinoid plates, maintaining complete optical continuity. The dominant sparite is syntaxial overgrowth. This grainstone is dolomitized in some places, as indicated by presence of dolomite rhombs. They occur sparsely as single crystals embedded in larger calcite grains or in fossil fragments. These isolated

*The Silurian seas are thought to have been rich in iron. Hunter (1962, p. 199) explains this release of iron into the sea as a result of low relief and increased intensity of weathering on exposed igneous or low-grade metamorphic rocks.

rhombs indicate replacement of calcite by dolomite. The light brown interclast is a dolomitic limestone fragment that probably is a ripped-up fragment of the muddy bottom. The rhombs are coated with organic material. As the dolomite rhombs grow, the organic material is displaced to the outside, forming a dark rim. Limonite may be responsible for slight brown staining around dolomite crystals. Some silicification of crinoid fragments is also present.

Hand Specimen Description BL2

The Brassfield represented by this sample is a coarse-grained greenish-gray and pinkish-gray fossiliferous grainstone. It contains seams of calcite and pyrite crystals. The rough surface shows encrusting bryozoa. A longitudinal section of a bryozoa, feathery in appearance, is seen on the cut, unpolished end of the rock. The pink and yellow grains are crinoid fragments.

Thin Section Study

This rock is classified, according to the Dunham classification scheme, as a fossiliferous grainstone. It consists of better preserved brachiopod and bryozoa fragments than BL1. Crinoids are present, with syntaxial overgrowth as in BL1. The dominant sparite is syntaxial overgrowth. It is important to point out that only single crystal fossil fragments show this, ruling out brachiopods and bryozoa. There is some micrite infilling of the brachiopods and bryozoa fragments; however, they are mostly filled with sparite. A trilobite fragment is also present, engulfed by the overgrowth of the adjacent crinoid fragment.

Also, an aragonitic fragment is present that could be either a gastropod or cephalopod. It is characterized by a black rim with recrystallization in the interior and niblets (small, sawtooth-like crystals) projecting from it into the exterior. These niblets grow in optical continuity and are also seen protruding from the outside rim of brachiopod fragments. There is replacement of fossil material by calcite and some dolomite. The pyrite has been altered to hematite as shown by the reddish-brown coating.

Depositional Environment of Brassfield Limestone
(as indicated by these two specimens)

These two samples are fragmental or clastic rocks, formed by deposition of fossil detritus, particularly crinoid fragments, in a biostromal deposit. The fossil debris was broken and worn as a result of shifting and movement by currents. Since these fossil fragments make up such a large part of the rock, it is probable that they were derived close to the area in which they were deposited. They were most likely deposited in a shallow sea which generally contained clear water and had constantly moving currents that kept regular bedding from being formed. Shallowness and small amounts of mud is indicated by large numbers of crinoids and bryozoa, which live only in an environment of this type. Lack of detrital minerals indicate no land or source nearby.

I now think that the Packer Shell is not equivalent to either the Dayton Formation or the Brassfield. The Dayton is believed to disconformably overlie the Brassfield in the outcrop area. The stratigraphic interval between, apparent in subsurface study, is missing in this area. If the "Packer Shell" is equivalent to the Oldham Formation, it pinches out under the Dayton Formation somewhere east of the locality that I visited (Figure 4). According to studies of Horvath, the Oldham Formation is exposed in Madison Co., Kentucky. He describes the Oldham Formation as gray to brown-gray thin to medium grained limestone/dolomite with interbedded blue-green shales (1964 PhD., p. 27). According to Horvath, the Oldham (Packer Shell) is commonly misidentified as the Brassfield in the subsurface.

Geologic History & Interpretation of Plate I

According to "Evolution of the Earth", by Robert H. Dott and Roger L. Batten, Europe and North America were separated until Devonian time, and during the Ordovician and Silurian periods these two continents and Africa were moving toward each other as the intervening proto-Atlantic plate was being consumed by subduction on both sides. Possibly, structural upheaval began first in the south during the latest Ordovician (Taconian Orogeny) and then spread progressively northward during the Silurian.

It is believed by Harold Williams and others, however, that a supercontinent was in existence by Silurian time. Regardless of the exact time period, the collision of North America, Europe, and Africa caused mountain building in the Appalachian mobile belt. Subsequent erosion of islands in this belt provided the detrital material for the formation of a deltaic system that formed in Ohio and had its source to the southeast. This delta was named the Keefer Delta by Horvath (1964) (Figure 5). The sands deposited by this system are called the "Clinton

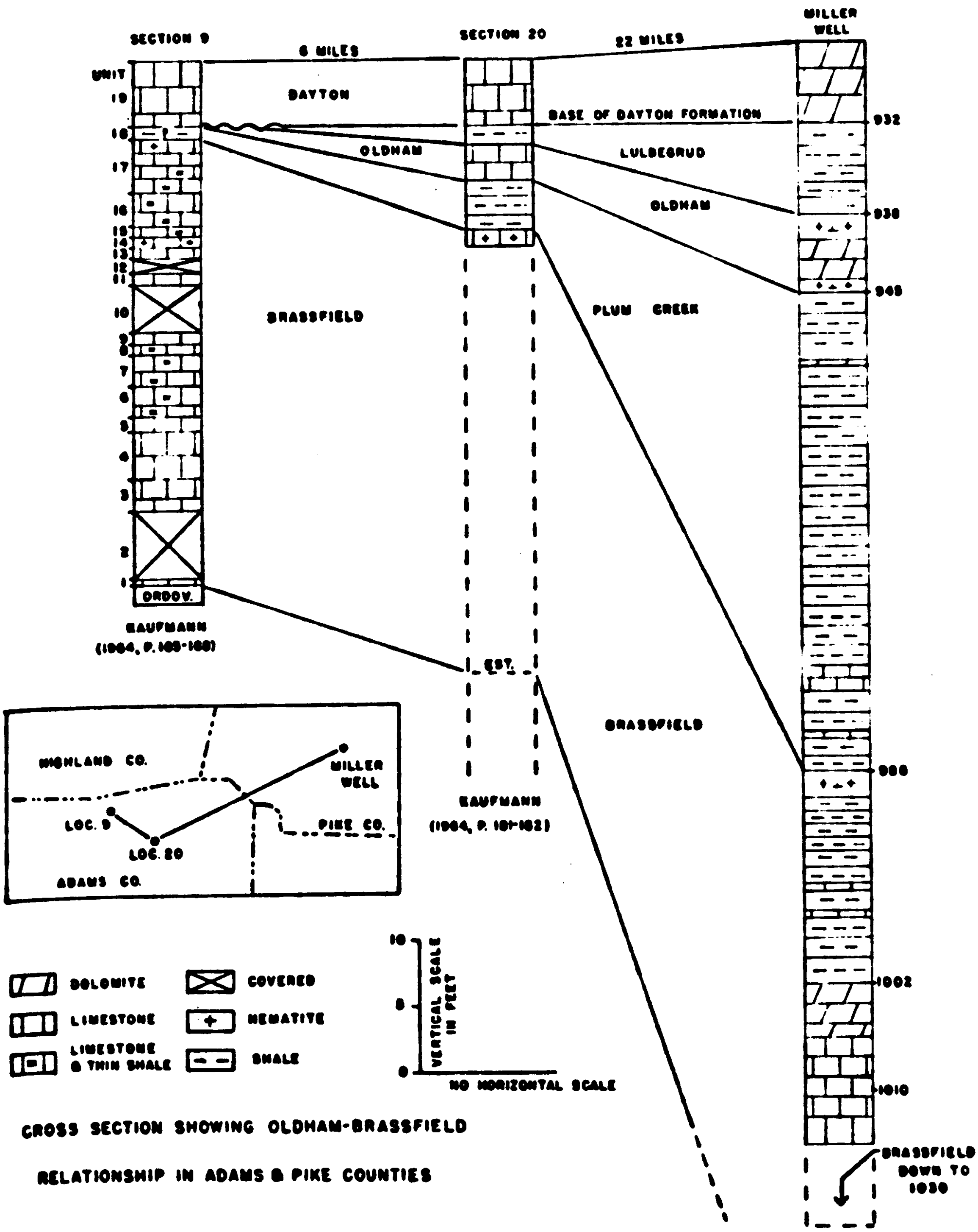


Figure 4 : Oldham-Brassfield relationship according to Horvath, PhD. dissertation, Stratigraphy of the Silurian Rocks of Southern Ohio and adjacent parts of West Virginia, Kentucky and Indiana, 1964.

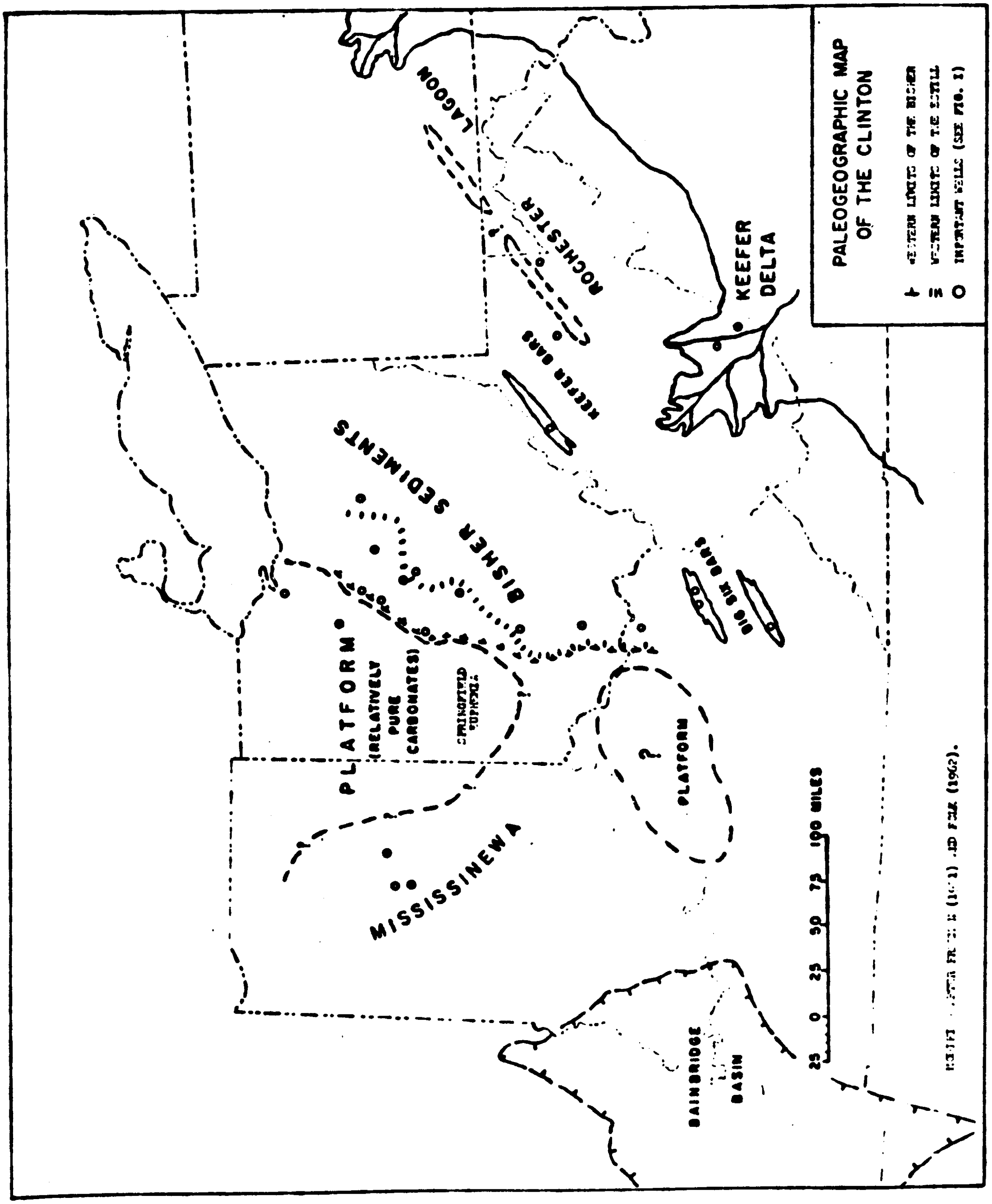


Figure 5: Paleogeographic Map of the Clinton Group
(Horvath, PhD. dissertation, 1964)

Sands" or "Clinton Sandstone". It is a major oil- and gas-producing formation in Ohio. This formation lies stratigraphically below the "Packer Shell". The "Clinton Sandstone" intertongues with the Brassfield Limestone in South-Central Ohio. The Brassfield lies stratigraphically below the "Packer Shell", is the western equivalent of the "Clinton Sandstone" in Ohio, and is represented on Plate I at well A (however is not labeled). The "Clinton Sands" are labeled "undifferentiated Clinton Sands" on Plate I. This means that it is not possible to correlate the individual sandstones and shales from well to well. They are discontinuous sandstone lenses and are popularly differentiated at the well-site by color into red and white Clinton through the microscopic analysis of samples. The "Clinton Sands" thicken to the east in Ohio. Epeirogenesis, (large-scale, gentle downwarping of the earths' crust), accompanied mountain building in the Appalachians and resulted in the formation of a broad geosyncline west of these mountains. Structural downbuckling seems to be the principle cause of geosynclinal subsidence. Also, the closer to the source, the greater the amount of coarser material deposited, (i.e. coarse sand). This, in conjunction with the deltaic system, is why we see a thickening of the "Clinton" to the east. The hinge line of the geosyncline is thought to be oriented in western Pennsylvania, paralleling the Appalachian mountain chain.

Corresponding, there is also a thickening of the strata between the "Packer Shell" and the base of the "Big Lime" from Morgan Co., York Twp., to Noble Co., Enoch Twp., (Plate I). From Fayette Co. through Perry Co., Pike Twp., a more or less parallel relationship exists between the "Packer Shell" and the base of the "Big Lime". This relationship suggests a shelf or platform area of the "Packer Shell" sea and corresponds to the platform discussed and illustrated by Horvath (Figure 5). Therefore, according to Plate I, the platform-basin hinge line lies between Morgan Co. and Perry Co. The geographic location of this hinge line is important in the exploration of hydrocarbons because oil and gas migrate up-dip and this hinge line serves as a trap for accumulation of these hydrocarbons. If one visualizes the base of the "Big Lime" as horizontal and simultaneously adjusts the base of the "Packer Shell" accordingly, (that is, increasing in depth to the east), the basin configuration is more readily seen.

At well A, the "Packer Shell" is less than five feet thick, suggesting a thinning out of the "Packer Shell" onto the platform. The "Packer Shell" most likely "pinches out" due to nondeposition, in the subsurface somewhere just west of well A. Well A may represent the western extent of the "Packer Shell". This interpretation contradicts the disconformable relationship discussed by Horvath and illustrated in Figure 4. Another possibility is that this five foot interval of limestone or dolomite belongs to the Brassfield Limestone, which is believed to disconformably underlie the Dayton in the outcrop area (page 9). If so, the "Packer Shell" has "pinched out" between wells A & B. This interpretation does not seem as likely. The Brassfield directly underlies this five foot interval of carbonate interpretated on this cross-section as "Packer Shell".

The shales overlying the "Packer Shell" are present throughout Central and Eastern Ohio and appear to follow basin geometry, indicating a transition from the "Packer Shell" into the shales. Thus, the upper contact of the "Packer Shell", as shown on Plate I, is a gradational contact, and not a disconformity. These shales have been given the name Lulbegrud Clay and were described as nonfossiliferous "blue" shale (Horvath, 1964, p. 30). This transition from the "Packer Shell" to the Lulbegrud Clay signifies a retreat of the sea if the clay is nonmarine. The Lulbegrud Clay could be pro-delta clay, associated with the deltaic system discussed earlier. It "pinches out" between wells A & B, most likely because of nondeposition.

On Plate I, the Lulbegrud Clay appears to grade upward into the Dayton Formation, a limestone and dolomite. A facies change takes place in the upper portion of the Dayton as it changes from a sandy limestone at well J into a sandy shale at well H and finally loses Dayton identity at well G. The Dayton sea may have had a different basin geometry than that of the "Packer Shell" sea. Another possibility is that the former "Packer Shell" sea transgressed; the time interval of regression was then relatively short. Perhaps this represents a small-scale fluctuation of sea level.

According to Horvath (1964, p. 340) the Estill Shale conformably overlies the Dayton Formation. It is described by Horvath as greenish-gray nonfossiliferous shale containing dolomite stringers. From the gamma ray logs on Plate I, we see that primarily shales overlie the Dayton, becoming more calcareous to the east.

In drillers' terminology, the shale and limestone between the "Packer Shell" and the "Big Lime" is called the "Rochester". This shale and limestone includes the Lulbegrud Clay, the Dayton Formation, and the Estill Shale.

Examining the sedimentary facies for Middle Silurian, (Figure 6), we see that most of the preserved rocks are carbonates and some shale that must have formed under a minimum influence of lands. Moreover, the deposits and their fossils suggest a former shallow sea with uniform conditions over an immense region. Figure 7 shows the interpretation of Middle Silurian paleogeography. It is assumed that marine Silurian strata originally covered all of the continent.

Suggestions for Further Study

A facies change most likely takes place in the "Packer Shell" as it extends from the platform area, where relatively pure carbonates are found, eastward into the basin. This can only be determined by careful study of the rock sample cuttings obtained at the well-site, along with cores if available. Exact depth control of the cuttings must be maintained throughout the drilling operation in order to correlate the cuttings with the correct formation. Samples are available from selected wells and are located at the Ohio Department of Natural Resources on Route 33. However, this is limited because only a few cuttings are kept from each ten foot interval of lithology. Also, several intervals are usually missing which could be an indication of confusion at time of selection at the well-site as to the correct depth from which they came.

By the nature of the cross-section, we are limited in our visualization of the extent and geometry of the "Packer Shell" and the sea

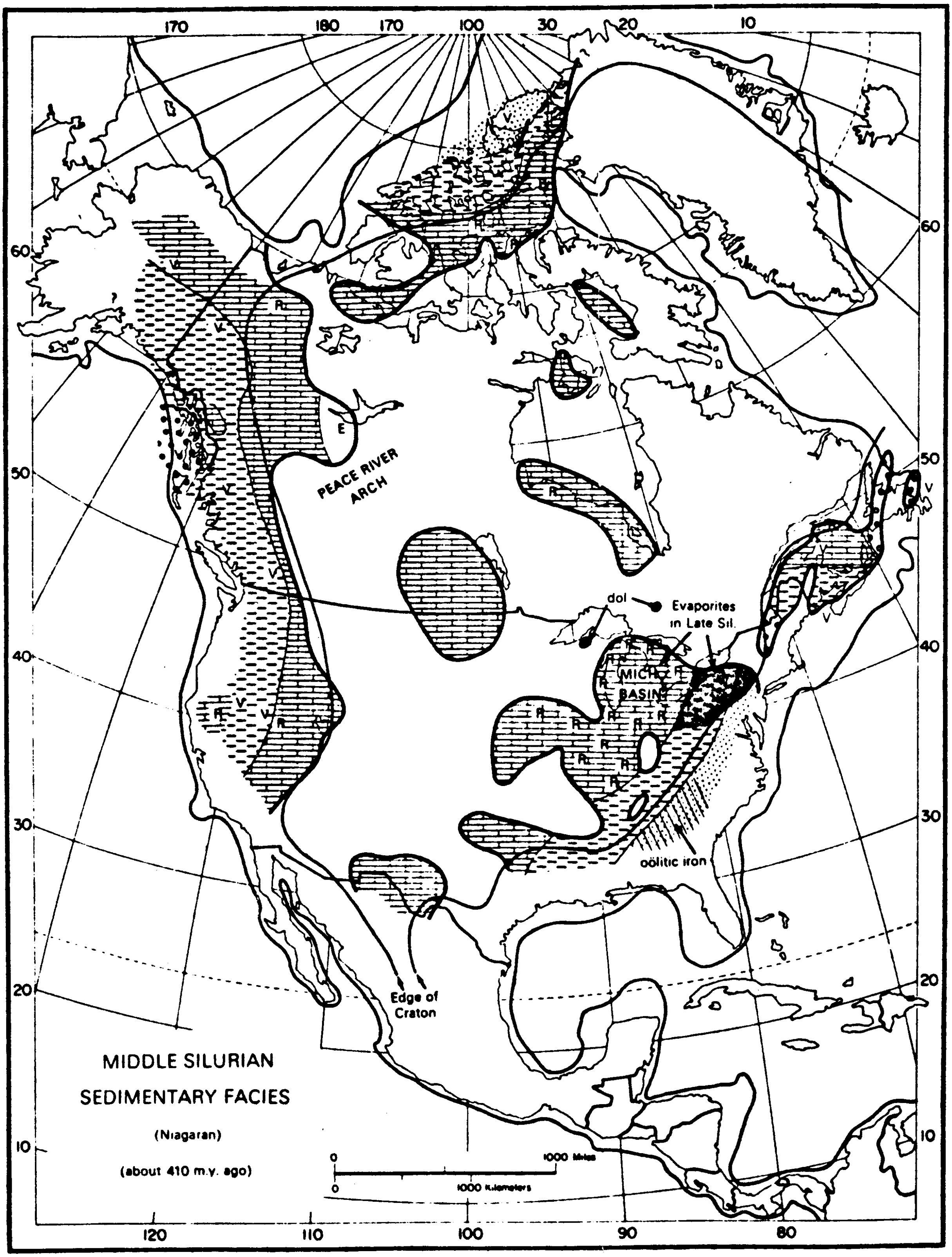


Figure 6 : Middle Silurian Sedimentary Facies
(<u>Evolution of the Earth</u>, Robert H. Dott and Roger L. Batten, 1976)

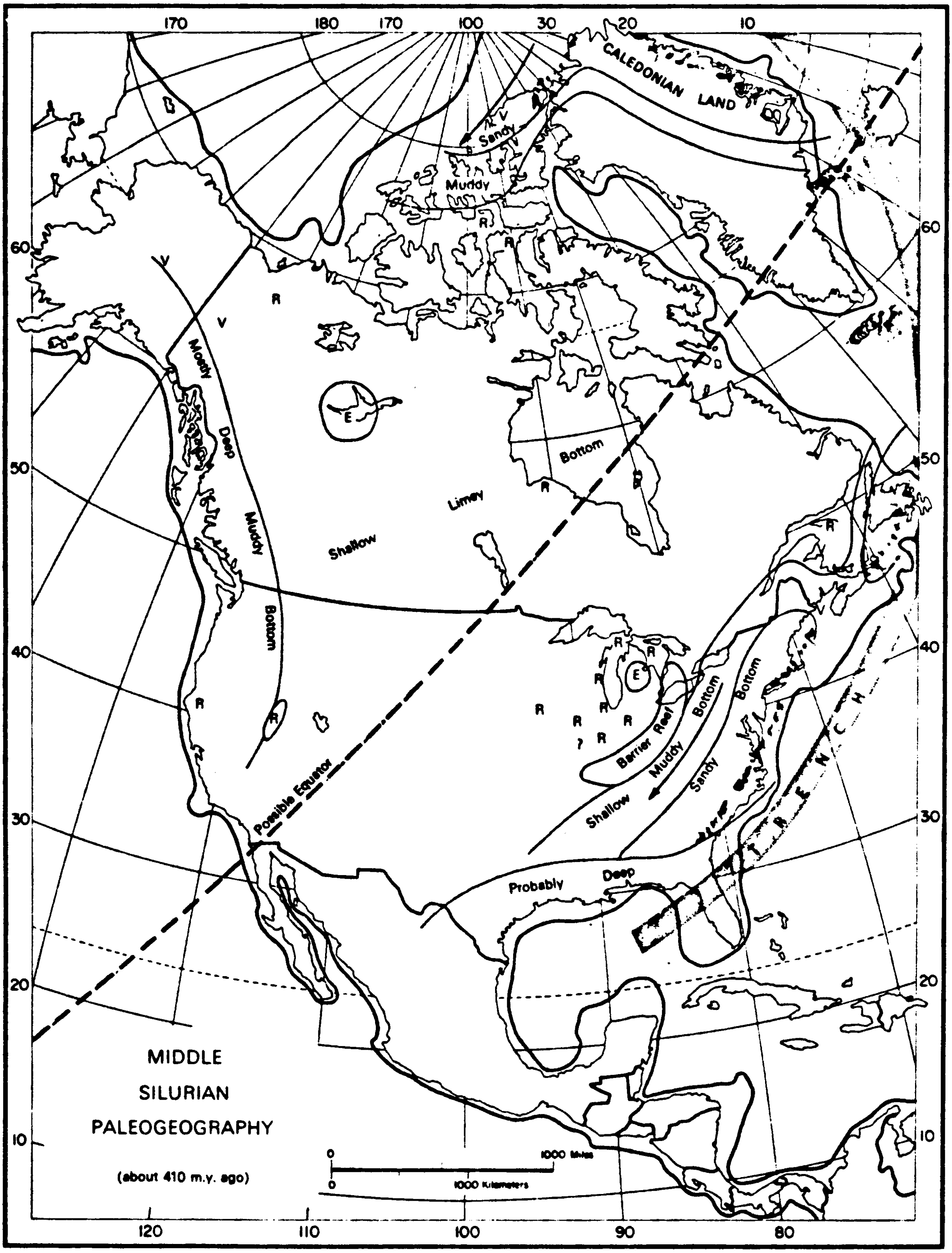


Figure 7 : Middle Silurian Paleogeography
(Evolution of the Earth, Robert H. Dott and Roger L. Batten, 1976)

in which it was deposited. An isopach map of the "Packer Shell" across Ohio is suggested for further study.

An independent study and construction of an isopach map of the Dayton Formation is necessary for further interpretation and determination of the extent of the sea in which it was deposited.

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